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TECHNICAL MEMORANDUM

SRL-0013-TM

NOTES ON RUNNING THE GENERALISED SYNTHETIC APERTURE RADAR SOFTWARE PACKAGE

D.M. McDONALD

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D.M. McDonald

S U M M A R Y

These notes refer to the Generalised Synthetic Aperture Radar (GSAR) Software Package developed by MacDonald Dettwiler and Associates. The version to which these notes refer is adapted to a VAX computer with a Floating Point Systems (FPS) array processor of the AP120B family. These notes are intended to complement the Operators Reference Manual particularly in areas which led to confusion on installation.

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1. INTRODUCTION

The version of GSAR which runs on a VAX computer with an AP120B-type array processor was obtained from the University of New South Wales Centre for Remote Sensing via Technisearch. Operating instructions are contained in the Operators Reference Manual. These notes complement and emphasise details in this manual, particularly in respect of areas which gave rise to problems on initial contact.

2. LOADING GSAR

The GSAR source code was delivered on a single tape in backup format. To compile, the appropriate privilege to access the array processor must be granted.

Initial compilation on a VAX 11/750 with FPS 5210 array processor, with no other users on the system, took about 65 min! The memory requirements for source and executable files is just under 17 000 blocks (at 512 bytes/block).

Before compilation, a change was made to GSAR DIR.COM, viz SET DEFAULT GSAR changed to SET DEFAULT [GSAR]. In the updated software, an appropriate assignment is made in command module GSARDEF.COM instead.

The heart of the GSAR suite is split into three programs controlled by command procedures:

PROCON, defining the sensor and processing configurations.

PRODEF, defining the processing details for a particular run.

RUNGSAR, controlling the processing sequence.

Only RUNGSAR requires the array processor. PROCON and PRODEF can be run without the array processor by loading only those modules required as follows:

```
@GSARDIR LIB
@BLDWRBLIB
@BLDRDBLIB
@BLDGPLIB
@BLDSRGR
@[-]GSARDIR PROCON
@BLDPROCON
@[-]GSARDIR PRODEF
@BLDPRODEF
!COPY EXECUTABLE FILES TO TOP DIRECTORY
 COPY [.*]*.EXE []*.EXE
```

PROCON and PRODEF can now be run as normal.

3. PROCON

(1) To run PROCON, type

@PROCON

(2) This program uses CONFIG.REF and SENSOR.REF files which <u>must</u> be present.

(3) UPPERCASE letters must be used throughout the configuration process.

(4) Numbers must be entered as floating point, eg 1.0310, not 1.0310E00.

(5) Option REPORT creates PROCON.PRN as a text file, but gives no user feedback on screen.

(6) Files PROCON.DBG and PROCON.ERR are created each with an initial length of 0 blocks, as soon as PROCON is started.

(7) The 'EXIT' option deletes .TEMP files (whereas an interrupt (CTRL/Y) leaves them).

PROCON comprises two main sections:

(a) Sensor data definition

This produces a file with sensor definition details. This section also produces a table of 'sensor performance parameters', including resolution and the linear and quadratic RMC (range migration correction) extent.

(b) Installation and configuration data definition

This produces a file (which also references the sensor file) comprising installation and configuration details. The installation details include intermediate file names and sizes. There are two intermediate files (referred to as file 1 and file 2: their function will be described under 'Running GSAR'). These sizes <u>must</u> be a multiple of 512 bytes.

The configuration details are defined in a sequence of steps. Modification of any step requires all the subsequent steps to be followed since many parameters depend on previously defined parameters.

In the configuration section, there are a total of nine different screens presented (some more than once):

(i) Input data definition (obtained from documentation)

- input CCT format
- prf encoding
- range gate delay encoding
- Doppler Translator encoding
- ADC/AGC Gain encoding
- Input Data size (orbit points, no. of video data elements)

(ii) Range compression module data

for each range presum ratio (1, 2, 4, 8, 16):

- specify the number of input samples, the location of the first sample in the FFT buffer and the number of samples in the forward FFT (a power of 2 up to 16384). To process the whole range swath, this must exceed the number of input samples;
- display the number of complex output samples (taking into account presumming and matched filter throwaway);

- specify the number of segments of 1024 and 512 samples. To process less than the full swath width, specify these segments so that they add up to less than the 'total available pixels after range compression'.

(iii) Doppler centroid operational mode specification

for each range presum ratio:

- specify how the Doppler centroid estimate will be created: the slope and intercept terms can be calculated either from the altitude and orbit data or estimated from the actual data, thus providing four options. This module also specifies details of the range lines used in estimating the Doppler parameters from the data.

Note: the range compression and Doppler centroid modules are presented in pairs for each presum ratio.

(iv) Range migration correction

Again, for each range presum ratio:

- specify details of range migration correction. In the present version of GSAR, linear range migration correction is always performed during range compression, so that the choice of 'linear range migration correction' is always 'No'. This question has been deleted in the Version 2 update.

(v) Look data definitions

For each azimuth presum ratio (1, 2, 4, 8, 16):

- select the fraction of 3 dB Doppler bandwidth to process.
- specify maximum allowable overlap of adjacent processed looks.
- For each look filter length (8192, 4096, 2048, 1024):
    - the maximum number of looks and number of good points per look is displayed;
    - the number of points to keep out of each look is selected;
    - a recommended value, based on the number of good points and the disk intermediate file size (file 2) is displayed as the default; this default value is:

      (a) a multiple of an increment determined by the filter length and the size of the segment chosen in the Range Compression module.

      (b) less than or equal to the specified filter length.

      (c) if less than the number of good points, it is proportional to the size of intermediate file 2, (subject to the specification of the Range Compression Module data).

Note that keeping more points than the recommended number may reduce the maximum number of looks obtainable.

Note also that the recommended number versus the number of good points for each look is not recorded in the REPORT file.

(vi) Azimuth processing performance summary

for each azimuth presum ratio: (1, 2, 4, 8, 16) and for each look length (8192, 4096, 2048, 1024) the nominal azimuth resolution and pixel spacing are presented.

(vii) Interpolation factor definition

for each azimuth presum ratio (1, 2, 4, 8, 16)

- specify the hard-copy pixel spacing in micrometres,
- specify the minimum range resampled pixel spacing,
- specify the minimum azimuth resampled pixel spacing for each look length.

The resampling factor (ratio of pixel spacings before and after interpolation) will be displayed in each case. These minimum pixel spacings are used as lower limits during the procedure definition (PRODEF) phase.

(viii) Gain specification

Specify the gains of the four relevant sections: range compression, forward transform gain, azimuth compression and interpolation/detection gain. This is a compromise between saturation and rounding errors.

(ix) Image storage format specification

for each azimuth presum ratio in turn:

- for each azimuth inverse FFT size, display the number of available points per azimuth line and the recommended number to keep;
- display the number of azimuth lines (ie range gates) after interpolation. The old version then specified the maximum number of pixels per line and the maximum number of lines.

Note that if the available pixels per line is zero, it suggests that disk file one is too small to store either the output of range compression or the output of the interpolation module. The options are either to process a narrower swath width or (if available disk space allows it) increase the size of disk file one. As mentioned above, limiting the size of disk file two will limit the number of points kept out of each look (and/or the number of looks).

The final step in PROCON is to go to EXIT mode to save the sensor and configuration files.

4. PRODEF

The process definition module defines the particular processing to be implemented on a given data file using the data stored in the specified configuration file.

(1) to run PRODEF, type

@PRODEF filename.ext

where 'filename.ext' is an existing processing-type file. The extension is mandatory. This file references a configuration file, and the configuration file in turn references a sensor file (as defined in PROCON).

(2) To extract the configuration filename from the current processing file, use the locally written program CHECK_NAME.FOR. If the configuration file does not exist, the message displayed on the screen is the uninformative 'error opening configuration file'. A correctly-named configuration file must be created before PRODEF will allow further specification even if a different configuration file is to be used.

(3) Note that when specifying the azimuth sub-sampling ratio, valid values are 0, 1, 2, 3 (corresponding to 2^0, 2^1, 2^2, 2^3) so that for no subsampling 0 is specified. However for the presum ratio, the actual value (1, 2, 4, 8 or 16) is entered. Thus for no presumming, 1 is specified.

(4) The three files:

PRODEF.DBG
PRODEF.ERR
PRODEF.PRN

are created when PRODEF is invoked, all with an initial size of 0 blocks.

(5) Presumming is performed on the input data in module CCTRP, to reduce the input sample rate and allow a survey-type mode. Thus data is processed in a shorter time for a given area, at the expense of resolution.

For range, presumming is performed in the frequency domain, ie a forward Fourier Transform, followed by a low pass filter, followed by an inverse Fourier Transform. In practice, this is implemented in the same process as range compression.

For azimuth, presumming is performed in the time domain with a FIR (finite impulse response) filter in CCTRP. To the processor it appears that the PRF has been divided down. This is essentially a band pass process centred on the range-dependent Doppler centroid frequency.

The range and azimuth presum ratios are set independently. However the GSAR manual indicates the possibility that if an azimuth presum ratio greater than 1 is specified, then the desired range presum ratio may not be acceptable owing to limited AP memory; if this situation occurs, a larger range presum ratio must be chosen.

(6) The azimuth sub-sampling factor specifies the length of the azimuth IFFT.

0 → 8192
1 → 4096
2 → 2048
3 → 1024

Consequently, if the length of the full azimuth matched filter exceeds 8192, then GSAR cannot process to full azimuth resolution.

(7) The azimuth subsampling factor affects:

- azimuth resolution: 0 (best) <--> 3 (worst)
- maximum no of looks: 0 (least) <--> 3 (most)

The azimuth presum ratio affects:

- azimuth resolution: 1 (best) <--> 16 (worst)
- amount of ground coverage for a fixed time interval:
  1 (least) <--> 16 (most)

(8) The autofocus module is used to update the B parameter used to calculate the *fm* rate required for azimuth compression. The principle behind autofocus is to examine misregistration of successive looks: if two looks are cross-correlated, then the position of the correlation peaks determines the misregistration. It is run only on the first azimuth block.

Thus the 'subsampling factor for autofocus' must be chosen such that at least two looks are guaranteed, with a maximum value of azimuth subsampling of 3 (as defined in the software, and corresponding to an inverse azimuth FFT of 1024 as described above).

(9) To progress to the second screen, the raw data tape must be loaded, even if a disk file is to be processed.

(10) PRODEF must be re-run before each run of GSAR (since GSAR changes and updates parameters in the processing file). However, after running PRODEF, the tape will be left at the 'BOT' mark and ON-LINE and need not be touched before running GSAR.

5. RUNNING GSAR

When PROCON and PRODEF modules have been run (the latter before each GSAR run for initialisation), then GSAR itself may be run. If GSAR is run immediately after PRODEF, then the tape will already be mounted.

(1) To run GSAR, type

@GSARDEF (for version 2), followed by
@RUNGSAR

Note that in Version 1, file assignments were done in a module within RUNGSAR.COM.

The response is to ask which processing file to use (eg PROCFILE.DAT) and the pathname to the main directory (eg DUA1:).

(2) GSAR then processes the modules in turn, with

(a) a message to say it has entered the module,

(b) error messages and warnings (if any), and

(c) a message to say the module is completed.

(3) To run GSAR, the two intermediate data files (the names of which are defined in the configuration file) must exist, be large enough and be a multiple of 512 bytes. They are initially set up with program 'FILLFILE'

which creates a file containing records of length 512 bytes. Most of the processing-intensive modules in GSAR write from one file to the other, which allows a resumption of processing after interruption without a total loss of processing time.

(4) .TMP files are created during processing (and then scratched); some disk space must be reserved for them.

(5) .ERR files are written whenever a warning is generated (one file per warning). The test tapes have produced these files mainly through bad tape records, up to about 150 files! Although these files are short, disk space must be available for them. .PRN and .DBG files are also produced. All these files can be deleted with @CLEANUP.

(6) GSAR updates a pass number in the processing file specified when a module is completed. If processing is interrupted and then restarted with @RUNGSAR, ASSIGNFIL will be rerun (version 1 only) and then the pass number stored by the processing file is compared with the expected pass number for each module in turn from the start of this module until the appropriate processing stage is reached, when processing will resume. Error-free processing is possible for those modules which write from one intermediate file to another (so that on interruption the file being read has not been altered). Only those modules which write 'in-place', namely SCT (corner turn) and RCM (range migration) modules cannot be interrupted without losing the entire run. Thus if these modules are interrupted, one must run PRODEF again to initialise and then start GSAR from the beginning.

(7) The program pauses whenever a tape must be loaded or changed. This occurs in two modules:

(a) CCTRP (reading raw data)

(b) CCTGEN (writing image tape)

On each occasion, physically load the tape, and put it on-line. Do not use the VAX/VMS 'mount' command. Type 'continue' to resume running.

(8) On completion, type

@CHECKTIME

for a terminal display of elapsed times for each module. These times are not processing times, so will vary according to the system load, and in the case of CCTRP and CCTGEN modules, on the time awaiting tape loading.

(9) In PROCON, the 'Doppler Centroid Operational Mode Specification' defines how the Doppler centroid estimate will be derived for each <u>range</u> presum ratio. If estimation from the original data is specified <u>and</u> the azimuth presum ratio is greater than one, then a Doppler centroid prepass must be run to make an initial estimate of where the beam is pointing relative to the zero Doppler location. If the azimuth presum ratio is specified as 1, then the Doppler centroid prepass is not required, irrespective of whether the estimate is derived from orbital data or signal data.

The sequence of steps for the Doppler Centroid Prepass is:

DCPREP
CCTRP
SCT
AZFFT

DPCEN
DCPEND

Following this, the standard sequence (reading from tape in CCTRP) starts. During the prepass mode, CCTRP performs all operations (excluding the azimuth presumming) for one block of 8192 lines. During the second run (in normal mode), it implements azimuth presumming as well.

6. TEST PROGRAMS

Running the eight tests is straightforward, except for tests 3 and 8. Test 3 checks out the autofocus module, and test 8 confirms that GSAR can process disk files as well as tape files, a sufficiently cumbersome procedure to ensure that it is unlikely to be used in practice.

Test 3: Autofocus

To test the autofocus module, data is processed using an incorrect azimuth FM rate, and the results with and without autofocus compared. Without autofocus, the result should be blurred. The Goldstone tape is most suitable.

(a) Use the standard configuration and sensor files.

(b) Run PRODEF (with the autofocus flag alternately set on and off).

(c) Start RUNGSAR

(d) Halt after BCALC and before CCINTRP and run PATCHBOE ie @[.DB]PATCHBCOE (NB: no underscores) and enter the percentage.

```
eg old B  .5153980E+08
   enter  2
   new B  .5257060E+08
```

(e) Start RUNGSAR

the modules already completed will be skipped.

(f) The utility program PEAKANAL may now be used to analyse the result.

Test 8: Data from disk

The procedure for running test 8 is as follows:

(1) Copy image data from tape to disk (eg disk file 2)

RUN[.UTIL]DISKINP

```
Note: Record length on tape (for SIR-B) is: 12420
      Name, disk file eg DUA1:[GSAR]FILE2.DAT
      Starting virtual block no on disk: 1
      DISMOUNT/NOUNLOAD MSA0:
```

(2) Copy volume Directory from tape to disk

@[.UTIL]HEADER

(3) Copy attitude and orbit data to files ATTDAT.DAT and ORBDAT.DAT by running PRODEF.

@PRODEF <processing filename>

Note that PRODEF must still specify TAPE in the first panel as the source of raw data. If test 8 immediately follows on from a run using the same tape, then the correct data will still be in these two files from the previous use of PRODEF and the step may be skipped.

(4) Run PRODEF

@PRODEF <processing filename>

This time, specify DISK in the first panel as source of raw data.

(5) Run GSAR

@RUNGSAR

7. UTILITY FUNCTIONS

Subdirectory [.UTIL] contains seven utility functions in version 1 of the software, summarised as follows:

FILLFILE	- fills a file with initial values - used to create large data files (ie the intermediate data files)
BFDUMP	- dumps the contents of a specified window of a binary file image onto a listing file (not as yet used)
DISKINP	- copies raw data from tape to disk
HEADER	- copies signal volume directory from tape to disk (supplied with version 1)
HISTGM	- as supplied, calculates statistical parameters from data file for several formats (1, 2 or 4 bytes signed integer or 4 bytes real). - modified to produce two versions, which also give the option of calculating the histogram from the data file; one version for signed integers and the other for unsigned integers (such as the detected image file).
PEAKANAL	- analyses a peak in two dimensions - applied to a detected (unsigned integer) image file
TAPEDISK	- copies an image data file from tape to disk on the VAX - can skip files - modified to produce a version which can skip records as well. - Version 2 supplied a program TPDISK which skips 2 files and 1 record, and thus is specific to the image files produced by GSAR.

Use of the two programs PEAKANAL and HISTGM will now be discussed in further detail.

(a) PEAKANAL

Enter subdirectory [.UTIL]. First copy image file from tape to disk.

(i) Compile TAPEDISK (or TDISK if records are to be skipped) via FOR TAPEDISK

(ii) Link via LINK TAPEDISK, [-.LIB]GPLIB/LIB, RDBLIB, OPENINP, OPENOUT

(iii) If necessary, use FILLFILE to create a file into which tape data is to be dumped. One of the intermediate files can be used for this purpose.

(iv) TAPEDISK starts from the first record in the file. If records are to be skipped, use TDISK.

(v) When running TAPEDISK or TDISK, physically mount the tape on the machine but do not use the DCL 'MOUNT' command. If TAPEDISK or TDISK crashes (or is interrupted), then the DCL command DISMOUNT/NOUNLOAD must be used before re-running.

(vi) PEAKANAL may be compiled and linked without using the array processor as follows from the default directory.

```
@[.LIB]BLDGPLIB
@[.LIB]BLDRDBLIB
@[.UTIL]BLDPKANAL
COPY[.LIB]*.EXE  *.EXE
COPY[.UTIL]*.EXE  *.EXE
COPY[.UTIL]PEAKANAL.COM  *.*
```

(vii) PEAKANAL uses the subroutines DGRAPH, DKWTRR and ERRORS in [.LIB]GPLIB and KILL_IO in [.LIB]RDBLIB (None of these invokes the array processor).

(viii) Four input data types are catered for:

IDTYP			ARRAY NAME
0	CR8	(8 bytes, complex)	INPUT (4096)
1	R4	(4 bytes, real)	INPR4 (8192)
2	I2U	(2 bytes, integer)	INPI2U (16384)
3	CR4	(2x2 bytes, integer)	INPCR4 (28192)

Thus IDTYP=2 is specified for an image file.

(ix) PEAKANAL.COM creates a parameter file PK.DAT and executes PEAKANAL.FOR. The input parameters (written to PK.DAT) are:

input data type (idtyp as above)
azimuth pixel spacing (in metres)
range pixel spacing (in metres)
input file name (up to 20 characters)
offset to start of file (no offset = 0)
line number of centre region
point number of centre region
number of bytes per line

Note that the standard GSAR output image file has one record of header information.

(x) The results of the analysis are written to PEAKANAL.PRN. The output includes a printout of input values around the specified pixel of interest and the position (and power) of the largest value pixel. Following interpolation and peak analysis, the point location, power and 3 dB azimuth and range widths are listed, together with the location and

power of the first side lobes (for both azimuth and range); and the integrated peak and sidelobes power. The range and azimuth impulse responses are then presented graphically.

(xi) Version 2 of GSAR also supplied a program ONEDPEAK, which performs a one dimensional peak analysis.

(b) HISTGM

As supplied, this program contained a coding bug which prevented it from working at all. (The wrong status value was checked after CALL DKWTRR in subroutine READIN. This however was corrected in the first update release.). In addition, the histogram option was disallowed. The amended version, HGMS, does include the histogram option. This program is however set up to perform calculations on 2's complement representation, eg it assumes data values are in the range.

-32768 to +32767 (for the 2 bytes per pixel case)

This program cannot therefore be used with (output) image files with unsigned integers (ie in the range 0 to 65535 in the above case).

The necessary modifications were made to produce a program HGM to accommodate this case.

Note that the changes required are:

(i) in subroutine STATVA change the numerical values of LIMIT(1) and LIMIT(2) and change CALL VUPS16(VUPS8) to CALL VUP16(VUP8)

(ii) in subroutine OUTPUT change the output statements for the histogram listing.

It is emphasised that capital letters must be typed (eg when asked whether the histogram option is required).

8. CONCLUSION

The Generalised Synthetic Aperture Radar package has been installed and tested on a VAX 11/750 with an FPS 5210 array processor. The package allows the processing of raw data from a number of SAR sensors provided the data is in a standard format defined for each sensor. Efficient and accurate use of the package requires some understanding of the parameters and options which may adjusted be as well as of the package structure. These notes are intended to aid this understanding in conjunction with the Operator's Reference Manual.

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17 SUMMARY OR ABSTRACT
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These notes refer to the Generalised Synthetic Aperture Radar (GSAR) Software Package developed by MacDonald Dettwiler and Associates. The version to which these notes refer is adapted to a VAX computer with a Floating Point Systems (FPS) array processor of the AP120B family. These notes are intended to complement the Operators Reference Manual particularly in areas which led to confusion on installation.

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